Universidade de Aveiro Departamento de Biologia
2007

Emanuel Ferreira Ribeiro

Seasonal variation in foraging habitat preference in Lesser Kestrel *Falco naumanni*

Variação sazonal da selecção de habitat de caça do Francelho *Falco naumanni*

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dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ecologia, Biodiversidade e Gestão de Ecossistemas, realizada sob a orientação científica do Dr. António Manuel da Silva Luís, Professor auxiliar do Departamento de Biologia da Universidade de Aveiro.

...para a minha familia.

...to my family

o júri

presidente	Prof. Dr. Fernando José Mendes Gonçalves
	Prof. Dr. António Manuel da Silva Luís
	Prof. Dr. João Eduardo Rabaça

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palavras-chave

Falco naumanni; preferência de habitat; Índice de Savage; Estepe cerealífera

resumo

Conhecer as preferências de habitat de uma espécie é crucial para a definição e implementação de medidas com objectivos de conservação.
Neste estudo analisamos a preferência de habitat de caça de uma espécie ameaçada, e a maneira como estas preferências se alteram ao longo da época de reprodução. A disponibilidade de cada tipo de habitat varia consoante as actividades agrícolas, como sementeiras, aragem ou ceifas.
Os resultados evidenciam que esta espécie selecciona diferentes tipos de habitat de acordo em cada fase do ciclo reprodutor. No início da época de reprodução, a espécie, prefere caçar em terrenos arados enquanto que no final prefere campos de cereais já ceifados nesta fase, e onde apenas há restolhos. As diferenças observadas não seriam detectadas caso não se considerassem as alterações de habitat inerentes às actividades agrícolas.
Os Francelhos preferem caçar em habitats com vegetação baixa e pouco densa provavelmente devido à maior disponibilidade de presas neste tipo de habitats. Machos e fêmeas não apresentam diferenças significativas em parâmetros de caça como a taxa de êxito ou o tempo de caça necessário para capturar uma presa. A taxa de êxito foi mais elevada em restolhos e no período incubação e mais baixa em terrenos arados e durante o período de pré-incubação. As aves despendem menos tempo para efectuar um primeiro ataque em cereal e do que em plantações de algodão.
Em plantações de cereais é necessário menos tempo para capturar uma presa enquanto que nos algodoais é necessário um maior esforço de caça.
O número de ataques por minuto de observação não é significativamente diferente entre biótopos.

keywords *Falco naumanni*; Habitat preference; Savage index; Cereal steppe

abstract

Knowing the habitat preference of a species is of crucial importance in order to sketch measures with conservational purposes. In this study we analyse the foraging habitat preferences of a threatened species and how they change through the breeding season. Habitat availability varies due to changes in agricultural activities such as ploughing, sowing, or harvesting. Our results evidence that this species select different habitat types according to breeding season stage. In the beginning of the season prefer to forage in ploughed fields while during chick rearing and post-fledging prefer cotton fields and cereal stubbles. Thus changes in agricultural activities must be considered in habitat selection studies. Lesser kestrels prefer to forage in low height and sparse cover, probably because of higher prey availability in this kind of habitats. Males and females don’t show significant differences in several hunting parameters. Success rate was higher in cereal stubble and during incubation and lower in ploughed fields and in the pre-incubation period. Lesser kestrels take less time to make a strike in cereal stubble and more in cotton plantations. In cereals prey capture takes less time while in cotton takes more hunting effort. The number of strikes per minute of observation didn’t varied significantly between habitats.

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Introduction

Habitat management for species conservation is normally based in recommendations derived from habitat preference studies. These studies attempt to identify the environmental factors that influence population behaviour and processes (Sutherland & Green 2004).

Iberian pseudo-steppes are characterised by flat relief, extensive cultivation of cereal in a traditional rotational system resulting in patches of cereal, fallow and ploughed land and stubble (Suárez *et al*. 1997). Due to its marginal yields, cereal steppes are changing towards intensive agriculture with the increase of irrigated areas and afforestation or abandonment of low productivity areas (Tucker & Heath 1994, Suárez *et al*. 1997). Despite the artificial nature of cereal steppes these areas support a high number of bird species with an unfavourable conservation status in Europe (Tucker 1997). Land use changes had been related to the decline of species like the great bustard *Otis tarda* (Alonso *et al*. 2005), little bustard *Tetrax tetrax* (Silva *et al.* 2004) or the lesser kestrel (Donázar *et al*. 1993, Bustamante 1997, Tella *et al*. 2000).

Several lesser kestrel habitat selection studies had been published and the majority conclude that forested areas, tree plantations and scrubland are avoided. Cereal fields and cereal stubble are positively selected in most studies (Donázar *et al*. 1993, Tella *et al*. 1998, Franco *et al*. 2004, Ursúa *et al*. 2005). Fallow land is generally positively selected (Donázar *et al*. 1993, Rocha 1996, Tella *et al*. 1998, Franco & Sutherland 2004, Garcia *et al.* 2006; but see Ursúa *et al*. 2005). Ploughed fields are considered a preferred habitat in some studies (Franco *et al*. 2004), an avoided habitat in others (Ursúa *et al*. 2005) also, in some other works, as an habitat used accordingly to its availability (Tella *et al*. 1998, Garcia *et al.* 2006). Tella *et al.* (1998) and Ursúa *et al.* (2005) consider field margins as an important foraging habitat while Franco *et al*. (2004) did not find a significant preference for this habitat.

Only two studies considered seasonal variation of habitat preferences (Franco *et al*. 2004, Ursúa *et al*. 2005) and both describe different selection patterns. Depending on the breeding cycle stage, lesser kestrels prefer to forage in different habitats. While in the south of Portugal they select grazed fallow, ploughed fields and cereal during the pre-hatching period (Franco *et al*. 2004), in the northeast of Spain birds prefer field margins and maize stubble (Ursúa *et al*. 2005). In the nestling period cereal stubble and grazed fields are preferred in south Portugal while, in northeast Spain, the preferred habitats are field margins (Franco *et al*. 2004, Ursúa *et al*. 2005).

This study aims at assessing the foraging habitat preferences of lesser kestrels during the entire breeding season. We expect variations in habitat preferences during the different stages of the breeding cycle and/or agriculture activities. Study habitat availability changes and how it influences the species foraging habits. Several foraging parameters are estimated and related to habitat characteristics.

Methods

Study area and study species

The study area is located in the La Palma del Condado municipality (Province of Huelva, Andalusia, Spain). The main crops are cereals (≈ 27%), sunflower (≈ 16%) and cotton (≈ 4%). Olive groves, orange groves and forested areas occupy a small portion of the area (altogether ≈ 9%). This area consists of an agricultural mosaic with the terrain divided in very small cultivated fields (mean field area 0.34 ha). The annual mean precipitation is 650 mm and the annual mean temperature is 19 ºC. During the lesser kestrel's breeding period maximum temperatures can reach 45 ºC.

The different cultures have different vegetative cycles and so the sowing and harvesting dates are different for each culture. While cereals, mainly *Triticum spp*., are sowed in December and harvested in June/July, sunflower *helianthus annuus* is sowed in March and harvested in August. Cotton *Gossypium spp*. is sowed in May and harvested in October. Sugar beet *beta vulgaris*, the main irrigated culture in the study area, is sowed in October and harvested in June/July (Bellerín 2007).

The lesser kestrel *Falco naumanni* is a small colonial threatened falcon that breeds in the Palearctic region and over-winters in Africa. Their breeding colonies are usually situated in holes in buildings, like churches, castles or rural buildings (Negro 1997). Their populations have dramatically decreased in the last decades (González & Merino 1990) and different causes of decline have been pointed out, such as agriculture intensification (Bustamante 1997), decrease in availability of nesting-holes (Franco *et al*. 2005) or pesticide use (Cramp & Simmons 1980). Lately, in some regions, this species had recovered its population numbers and genetic diversity (Prugnolle *et al*. 2003).

Field procedures

The fieldwork started in the first week of March 2007 and lasted until end of July. Six transects were defined inside a 4-km circular buffer centred in the colony and carried out by bicycle at a constant speed (around 5 Km/h) once a week. In order to avoid sampling biases the start point of the transect, start hour and movement direction were selected at random each time the transect was visited. Each time a bird or flock was detected we determined sex, age, flock size and composition, distance to the observer, direction of the observed individual, in relation to magnetic north, altitude of flight and activity using a high precision rangefinder (Leica® - Laser Locator 1.0; distance: $\pm$ 1m <1000m; Compass $\pm$ 0.5º). Using a PDA with GPS (Thales® – MobileMapper CE) we registered the observer's position with high accuracy ($\pm$ 5m). This procedure allowed determining the accurate location of each bird observed and then assign each observation to the habitat type used. Each bird was followed until a prey was captured or until the moment the bird left the observation field and the hovering time, number of strikes, prey captures attempts and time until first capture were recorded.

Simultaneously soil use information was collected within a 4Km radius of the colony. A land-use map was generated in a geographic information system (Arcview 3.2) and soil occupation information was collected by monthly field visits recording type, height, density and irrigation data of vegetation within each field.

Statistical analysis

The lesser kestrel's breeding season was divided in three periods: Pre-incubation (March and April), Incubation (May) and nestling (June and July).

The study area was divided with a 250m resolution grid formed by 992 cells. Cells that were situated at more than 700m from a transect were not considered because kestrels could not be detected further than 700 m from a transect. Statistical analyses were performed on the 726 remaining cells. For each cell we determined several measures of habitat availability and quality like percentage of area occupied by each habitat or the length of margins within the cell.

To determine the kestrel land-use preferences, we used only the first record of each contact with a lesser kestrel in hunting activity. We used the Savage selectivity index, $\omega_i = U_i/p_i$, where U_i is the proportion of birds hunting in habitat *i* and p_i the proportion of available habitat *i*. This index ranges from 0 (maximum negative selection) to infinite (maximum positive selection), 1 indicating no selection. In order to test the null hypothesis that birds use foraging habitat in proportion to its availability we compared the statistic $(\omega_i-1)^2/(S.E_{\omega i})^2$ with the critical value of a Chi-square distribution with one degree of freedom. The Standard error of the index (S.E) was calculated as $\sqrt{}(1-p_i/(u.p_i)$ where *u* is the total number of contacts with lesser kestrels foraging (Manly *et al.* 1993, Tella & Forero 2000, Garcia *et al*. 2006). All comparisons were corrected for multiple tests using Bonferroni criteria (Rice 1989).

We used Mann-Whitney tests to search for differences habitat diversity index, amount of margins and distance to the colony comparing cells with hunting birds against cells without. The mean values are given as the mean value $\pm$ 1 S.E.

Results

A total 203 contacts with individual lesser kestrels in hunting activity was obtaining during this work. No Lesser kestrel was ever detected hunting over any arboreous habitat, water, roads or buildings.

Lesser kestrels positively selected cotton fields (ω_i=2.99; $p<0.001$), ploughed land (ω_i=2.15; $p<0.01$), sunflowers (ω_i=1.49; $p<0.05$) and cereal fields (ω_i=1.51; $p<0.001$). Sugar beet, potatoes chickpea and fallow land were selected accordingly to availability (ω_i>0.51; $p>0.05$). Other habitats and shrubland were avoided (ω_i=0.05, $p<0.001$ and ω_i=0.07, $p<0.01$; respectively - fig. 1-A). Considering the entire season, the values of Savage selectivity index ranked the considered habitats as follows (signs of selection in parenthesis): Cotton (+) > Ploughed fields (+) > Sunflower (+) > Cereals (+) > Irrigated (0) > Fallow land (0) > Scrub land (-) > Other (-).

We observed 61, 34 and 108 hunting individuals during each period (pre-incubation, incubation and nestling, respectively, fig. 1).

The availability of each habitat type showed considerable variations during the lesser kestrels breeding season. Cereal area was constant but, due to harvesting activities, it suffered an important structural change. Ploughed fields diminished while sunflower and cotton plantations increased. Irrigated area remained constant until May and diminished towards the end of the season (fig. 2). Forest, vineyards, and olive and orange groves remained constant during the whole season.

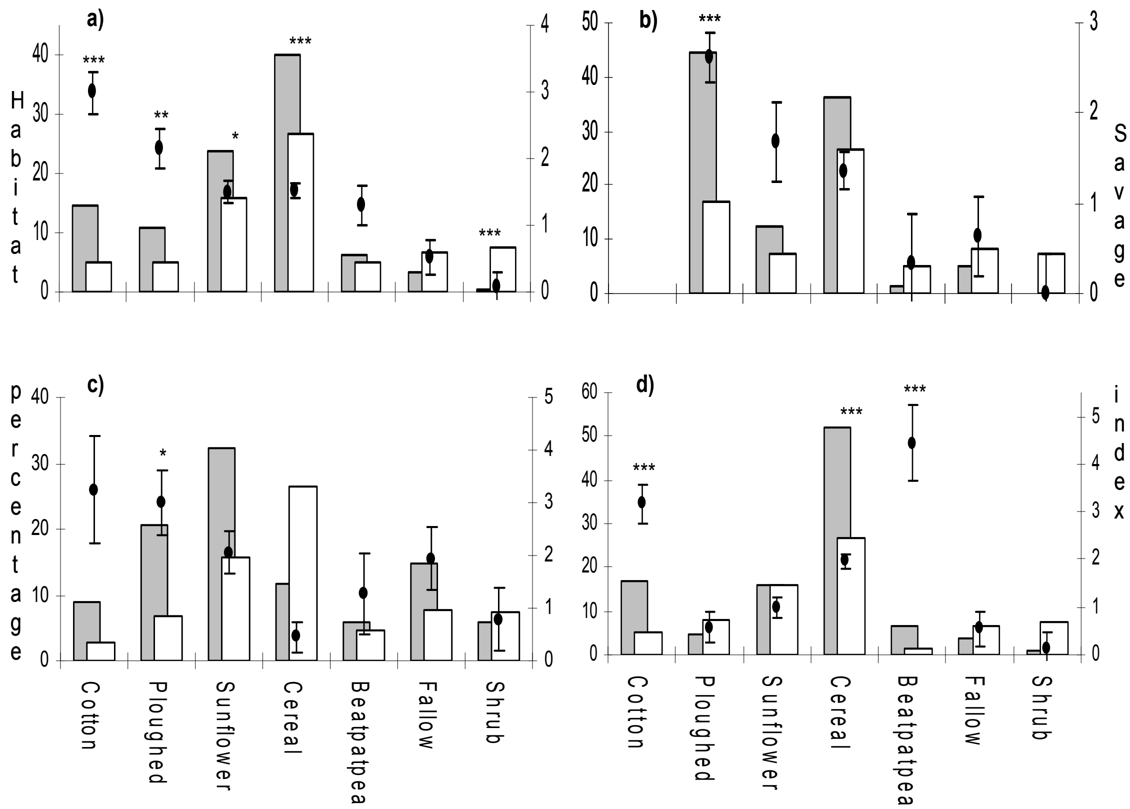

Figure 1 - Percentage of available (white) and used (grey) habitat. Savage selectivity index (black points) ± S.E. a) entire season; b) before laying; c) incubation; d) after hatching. (* - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$).

Before laying, ploughed land (ω_i=2.62, p<0.001) was the only habitat selected significantly more than expected according to its availability. All the other habitats were used according to their availability (ω_i<1.37, p>0.05; for all cases).

As in the pre-laying period, during incubation the only preference exhibited by lesser kestrels was towards ploughed fields (ω_i=3.00, p<0.05) while the remaining habitat categories were selected accordingly to their availability (fig. 1-C).

In the nestling period irrigated cultures (ω_i=4.45, p<0.001), cotton (ω_i=3.17, p<0.001) and cereal (ω_i =1.96, p<0.001) were positively selected. The remaining variables were used accordingly to their availability (ω_i <0.99, p>0.05; for all cases- fig.1-D).

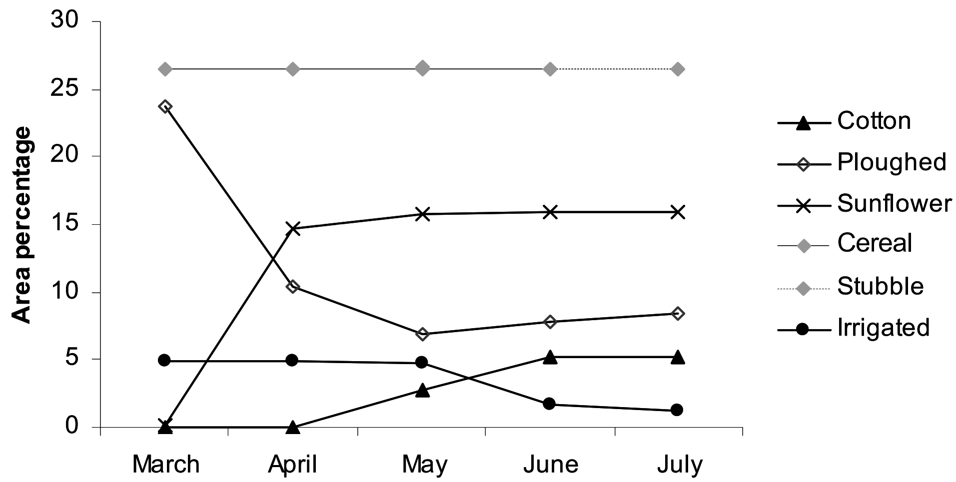

Figure 2 – Seasonal variation of the habitat availability during the lesser kestrel's breeding season.

The cells with absence of lesser kestrels had highest mean border length (*U*=12.97, *p*<0.001). Diversity index (J') and distance to colony did not show significant differences (table 1).

Table 1 – Mean values (± SE) of each variable in cells with and without observations of lesser kestrel foraging activity. Comparisons using Mann-Whitney test (*U*).

	Hunting activity		**Strikes**		**Successful strikes**	
	Without	*With*	*Without*	*With*	*Without*	*With*
Human	10.58±21.40	4.87±10.56***	10.25±20.88	4.01±9.02***	10.04±20.63	4.26±9.64**
Cotton	3.70±12.97	10.62±20.71***	3.93±13.50	13.10±21.60***	4.05±13.71	14.71±22.26***
Ploughed	4.63±11.86	6.86±13.06*	4.86±12.12	6.38±12.02*	4.95±12.28	5.89±10.14*
Sunflower	14.34±21.01	22.75±24.15***	14.96±21.19	23.06±25.37***	15.32±21.36	21.69±25.92**
Trees	11.41±20.22	1.65±7.00***	10.79±19.77	0.56±1.52***	10.48±19.56	0.63±1.62***
Other	0.23±2.20	0.28±2.44	0.27±2.38	0.00±0.00	0.26±2.34	0.00±0.00
Irrigated	4.14±11.92	8.48±14.03***	4.24±11.74	10.35±16.03***	4.48±12.06	9.75±15.17***
Fallow	7.20±16.50	4.78±15.17**	7.13±16.56	3.89±13.64**	7.20±16.76	2.03±8.33***
Unknown	10.57±19.78	1.92±7.04***	9.94±19.24	1.55±6.61***	9.66±19.02	1.92±7.56***
Cereal	24.51±27.91	35.35±28.09***	25.51±28.29	34.05±26.77***	25.60±28.13	35.90±27.88**
Shrub	8.68±16.99	2.45±6.31***	8.12±16.45	3.06±7.69***	7.96±16.25	3.22±8.30*
Distsilo	2654.77±993.73	2469.39±1033.08	2650.47±996.95	2389.23±1024.85*	2638.97±1003.30	2428.89±984.55
Borders	2001.83±984.67	1670.37±796.63***	1972.47±982.48	1699.55±735.11*	1968.48±974.72	1653.66±750.96*
Diver	0.34±0.12	0.33±0.15	0.34±0.16	0.33±0.13	0.34±0.16	0.33±0.14
n	595	131	645	81	665	61

— *** - p<0.001; ** - p<0.01; ** p<0.05

Considering the percentage cover of vegetation (table 2), lesser kestrels preferred medium ([40-60[%: ω_i=2.86, p<0.001) to sparse vegetation ([0-20[%: ω_i=1.42, p<0.05) and avoided high density ([80-100[%: ω_i = 0.54, p<0.001). These tendencies are similar in the pre-laying and incubation periods, whereas in the nestling period birds select vegetation with 20 to 60 % cover (ω_i=2.88, p<0.01).

Table 2 – Selection index (ω_i) standard error (S.E.) and significance level (p) for vegetation height and cover before laying, during incubation, after hatching and in the total breeding season.

	Before Laying			**Incubation**			**After Hatching**			**Total**		
Height (cm)	ω_i	S.E.	p	ω_i	S.E.	p	ω_i	S.E.	p	ω_i	S.E.	p
[0-20[	2.376	0.219	<0.001	3.512	0.452	<0.001	1.485	0.152	<0.01	2.117	0.129	<0.001
[20-60[	0.855	0.222		2.081	0.449		0.946	0.223		1.090	0.154	
[60-100[	1.175	0.301		0.654	0.208		2.384	0.265	<0.001	1.113	0.132	
[100-150[	0.000	0.604		0.000	0.547		0.956	0.233		0.832	0.225	
[150-	0.000	0.392		0.581	0.743		0.000	0.302	<0.01	0.056	0.227	<0.001
Cover (%)												
[0-20[	2.053	0.228	<0.001	2.331	0.512	<0.05	0.609	0.259		1.423	0.161	<0.05
[20-40[	0.479	0.680		1.170	0.452		2.818	0.586	<0.01	1.621	0.333	
[40-60[	3.753	0.522	<0.001	10.514	0.883	<0.001	1.910	0.185	<0.001	2.856	0.189	<0.001
[60-80[	0.967	0.230		0.960	0.671		1.044	0.180		1.042	0.143	
[80-100]	0.214	0.235	<0.01	0.373	0.181	<0.01	0.951	0.184		0.544	0.112	<0.001

Foraging lesser kestrels prefer to hunt in low vegetation areas ([0-20[cm: ω_i=2.12, p<0.001) and avoid areas with tall vegetation (>100cm: ω_i=0.06, p<0.001). During the pre-laying and incubation periods birds select fields with a maximum height of 20 cm (pre-laying: ω_i=2.38, p<0.001; incubation: ω_i=3.51, p<0.001). In the nestling period birds select low ([0-20[cm: ω_i=1.49, p<0.01) and medium vegetation ([20-60[cm: ω_i=2.39, p<0.001) and avoid the tallest one (>100cm: ω_i=0.00, p<0.001).

From the 203 birds observed in hunting activity, it was possible to follow 195 individuals in hunting sequences. On average each individual was observed for 2.70 ($\pm$0.19) min from which 2.42 ($\pm$0.19) min were spent in hunting activities. From time of contact to first strike individuals spend, on average, 1.95 ($\pm$0.13) min and to prey capture 2.25 (±0.22) min. Average success rate was 68% and kestrels made a strike, every 21 seconds of observed hunting activity.

Males and females take the same time to make a first strike (1.88±0.19 and 1.67±0.33 min, respectively) (*U*=550.5; *p*>0.5) and to capture a prey (1.98±0.25 min; *U*=297; *p*>0.6). Success rate was similar in both sexes (75%). No differences were detected in the number of strikes performed per minute between males (0.35 strikes/min) and females (0.29 strikes/min; *U*=1249.5; *p*>0.4).

Lesser kestrels take less time to make the first strike in cereal stubble, fallow land and cereal while they take more time in sunflower and cotton or ploughed fields (Table 3), though this differences were not significant (*U*>238; *p*>0.07). Cereal stubble, fallow land and irrigated cultures showed higher success rates (84%; 82% and 80%, respectively) while cotton and ploughed fields had the lowest (53% and 46%, respectively). Although significant differences were encountered only between cereal stubble and cotton fields (*U*=106.5; *p*<0.05) and between cereal stubble and ploughed fields (*U*=157.5; *p*<0.01). More strikes per minute were performed in irrigated fields, cereal stubble and cotton (0.57; 0.45 and 0.44, respectively) but differences were not significant.

Table 3 – Success rate, number of strikes per minute of observation, time needed to perform a strike (± S.D.) and time needed to capture a prey (± S.D.) in each habitat type. Values between brackets represent sample size.

	Stubble	Fallow	Cereal	Irrigated	Sunflower	Ploughed	Cotton
Success rate	0.84 [31 strikes]	0.82 [11 strikes]	0.76 [17 strikes]	0.80 [5 strikes]	0.66 [29 strikes]	0.46 [26 strikes]	0.53 [17 strikes]
Strikes/min	0.45 [73.1 min]	0.39 [36.5 min]	0.21 [100,82 min]	0.57 [10.55 min]	0.33 [101.15 min]	0.35 [113.68 min]	0.44 [42.88 min]
Time to first strike	1.56±0.21 [18 ind]	1.67±0.36 [5 ind]	1.69±0.34 [13 ind]	1.83±0.59 [4 ind]	1.87±0.32 [18 ind]	2.12±0.34 [21 ind]	2.42±0.45 [8 ind]
Time to prey capture	2.15±0.57 [16 ind]	2.35±1.33 [2 ind]	1.69±0.45 [9 ind]	2.29±0.51 [3 ind]	2.21±0.48 [12 ind]	2.54±0.55 [11 ind]	3.21±0.56 [7 ind]

The success rate, time to the first strike, time to prey capture and number of strikes per minute varied during the breeding season. Success rate was lower in the pre-incubation (42%) and higher during the incubation period (87%) (U=124; p<0.001). Time to the first strike and time to prey capture were higher in the pre-incubation period (2.15$\pm$0.25 and 2.66$\pm$0.37 min, respectively) and lower in the incubation period (1.55$\pm$0.29 and 1.86$\pm$0.44 min, respectively) (U=244; p<0.05, for time to first strike; U=77; p<0.01, for time to prey capture). The lowest numbers of strikes per minute of observation were detected before incubation (0.31 strikes/min) and the highest ones during incubation (0.39 strikes/min) but differences were not significant (U=784; p>0.8). In the nestling period all parameters values were intermediate (75% success rate, 0.36 strikes/min, 1.96 min to the first strike and 2.03 min to prey capture). There were no significant differences between parameters during incubation and nestling periods (U>464, p>0.2). Although, comparing the pre-incubation period and the nestling period, there were significant differences in the success rate (U=422, p<0.001), time to perform the first strike (U=769, p<0.05) and time used to capture a prey (U=223.5, p<0.05).

Discussion

Due to the agricultural nature of the study area, habitat type is constantly changing along the lesser kestrel's breeding season causing variations in the availability of foraging habitat (Ursúa *et al*. 2005). A ploughed field, in the beginning of the breeding season, can become a sunflower field by the end. Our results suggest that these variations should be taken into account in foraging habitat selection studies. When comparing results we see that cereal or cotton fields are preferred habitat types if we consider only the final land use. Although if we consider land use changes, it becomes clear that this two habitats are selected only after egg hatching, when cereal fields are already harvested and cotton fields have low and sparse vegetation cover.

Garcia *et al.* (2006) stated that in the beginning of the breeding season (April) lesser kestrels preferred to hunt in unploughed fallow and that ploughed fields were used accordingly to its availability. Our results show a different tendency since ploughed fields were significantly more used than expected, while fallow land was used accordingly to its availability during all season. Tella *et al*. (1998) discovered that, when foraging in ploughed fields, lesser kestrels take less time to make a strike, and that they had a success rate of 0.74 prey/strike. So this habitat type offers kestrels suitable hunting conditions. In the beginning of the breeding season, the diet of this species in this colony shows high levels of mole cricket *Gryllotalpa gryllotalpa* and earthworm (*Lumbricus* sp.) (Kieny 2003). The mole cricket is considered an important prey during egg formation stage (Choisy *et al*. 1999, Rodríguez 2004). The presence of these prey types during the pre-incubation period reinforces our finding that kestrels select ploughed fields since, in this type of habitat, these preys cold be more exposed due to agricultural activities.

By the end of the breeding season (chick rearing and chick dispersion), foraging Kestrels prefer cereal, cotton and sugar beet fields. These results partially agree with those of several authors (Tella *et al*. 1998, Franco *et al*. 2004, Donázar *et al*. 1993) that state that cereal stubble is preferred by this species. Cotton is an unusual culture type in other areas and so there are no other studies that support our findings. Although, Rodríguez (2004) found that, in this type of land use, the numbers of adult orthoptera were high particularly before the first pesticide application. This finding justifies the selection of this habitat by lesser kestrels.

Vegetation structure determines prey availability, and this is of critical importance for aerial predators since visibility can be affected by vegetation density or height (Shrubb 1980, Bechard 1982, Toland 1987, Garcia *et al*. 2006). In our study birds preferred to forage in low and sparse vegetation. This is most probably linked to prey availability since orthopteran prey is more abundant and larger in high and dense habitats like semi-natural vegetation (Kevin *et al*. 2003, Franco 2004, Rodríguez 2004). During the nestling period kestrels alter their preference and forage more than expected in higher habitats than in the other periods. This may be due to the selection of cotton plantations in the same period or due to orthopera movements motivated by harvesting activities.

Field or road margins are considered as a preferred habitat type for this species (Tella *et al*. 1998, Tella & Forero 2000, Ursúa *et al*. 2005). In this study we didn't consider the field margins as a habitat type due to the difficulty of placing an foraging animal in that lineal structure and, in the case of our study area, due to small size of cultivated fields, we could not be sure if a bird hovering near a field limit was hunting on the margin. So we test the relevance of this variable in a different way expecting that the amount of margins had a positive influence in the presence of hunting birds. Although, our results show that cells with presence of hunting individuals had lower mean margin length that those without hunting birds.

As expected with small falcons with little sexual dimorphism, there were no differences between sexes in foraging parameters like the time needed to perform a first strike, time to prey capture, success rate or strikes per minute. The differences encountered between habitats occurred in habitats with very different vegetation structures. Cereal stubble has a low density and low height vegetation structure, cotton usually is a denser and higher habitat while ploughed has no vegetation at all. We would expect that the number of strikes performed per minute of observation would vary significantly between habitats accordingly to different prey density (Rodríguez 2004).

In the pre-laying period lesser kestrels needed more time to capture a prey, had a lower success rate and preformed less strikes per minute. The abundance of orthopteran prey in this period is lower than in the remaining ones (Ribeiro 2006), making it difficult to find and capture prey in this period. It would be expected that in the nestling period lesser kestrels had higher success rates and shorter times to capture a prey. In this study, these parameters were similar during incubation and nestling periods, indicating that prey availability is similar in both periods.

Prey availability and prey abundance are known to be different in different habitats (Tella *et al.* 1998, Rodríguez 2004). So the time needed to make a first strike or to capture a prey is expected to be shorter in habitats with high prey availability while success rate and strikes per minute are expected to be higher. In this study, lesser kestrels had higher success rates and shorter times to make a strike or capture a prey in cereal stubble indicating that this habitat type offers ideal conditions for hunting. On other hand, in irrigated cultures lesser kestrels performed more strikes per minute but had a low success rate. This may point to high abundance of prey in this habitat but due to the density and height of vegetation, preys are difficult to capture.

Tella *et al*. (1998) determined the time needed for the first strike as well as the success rate of lesser kestrels in different habitats in traditional agro-grazing systems and pseudo-steps intensively cultivated. Comparatively, in this study birds take longer to make the first strike in ploughed fields (2.12 $\pm$ 1.56 min) and less in cereals (1.64 $\pm$ 1.03 min). Similarly, the success rate was higher in cereals (83.9%) and lower in ploughed fields (46.2%).

Cereal stubble seams to be the ideal habitat for this species. The low density and height enhances the probability of finding and caching a prey. Besides this, the availability of this habitat arises during the nestling period assuming a critical importance in the breeding success of this species. A sequential harvesting of cereal fields would increase the availability and trophic capacity of cereal stubble and increase the lesser kestrel's breeding success. The same strategy could be applied in the sowing period in order to maximise the time of availability of ploughed fields and preys such mole crickets. This would increase the female's body condition during the egg formation and so better clutch sizes and incubation capacity.

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